Emittance Correction in the 2006 ILC Bunch Compressor

P. Tenenbaum
ILC-NOTE-GDE-RTML-2007-01
SLAC-TN-07-004
February 27, 2007

1 Introduction

A recent study [1] has indicated substantial potential emittance growth in the ILC bunch compressor due to quad misalignments, BPM misalignments, and pitches in the RF cavities. Table 1 summarizes several results from [1]. In this simulation, quad misalignments and cavity pitches are Gaussian distributed and are considered with respect to the nominal survey line; BPM misalignments are also Gaussian-distributed but are considered with respect to the quadrupole axis. It is assumed that the BPM offsets with respect to the quads are found in a previous quad-shunting BBA step which is not simulated.

Table 1: Summary of a subset of results from [1], see for example page 14 of [1].

Quad Offset (μm)	BPM Offset (μm)	Cavity Pitch (μrad)	Correction	Mean growth (nm)	90% CL Growth (nm)
150	7	0	KM	6.8	15.1
150	7	0	KM + Knobs	2.1	4.7
150	7	300	KM + Knobs	9.2	17.6

In this study we seek to repeat the studies documented above, and additionally to perform a study in which additional dispersion bumps are used to further reduce the projected emittance.

2 Details of the Study

In this study of the bunch compressor, several techniques are used: Kick Minimization Steering and Global Dispersion Knobs.

2.1 Kick Minimization Steering

The implementation of Kick Minimization Steering (KM) used here is identical to the one reported in [2]. In particular, the weight ratio between 1-to-1 steering and zeroing the corrector-minus-BPM reading is set as described in [2], so that the optimum result (in this case, this means the minimum of χ^2) should be achieved when the RMS BPM reading is 150 μm and the RMS corrector-minus-BPM reading is 7 μm. The beamline is divided longitudinally into regions, and each region is KM steered 3 times before the next region is steered.

2.2 Dispersion Knobs

There are 4 skew quads in each bunch compressor wiggler which can be used for emittance tuning. The first pair of skew quads are set in a $-I$ matrix from one another at points of equal dispersion, so that antisymmetric excitation of the magnets will result in a pure dispersion. The second pair of

Work supported by US Department of Energy contract DE-AC02-76SF00515

skew quads in each wiggler has an identical optics, and they are set 90° away in betatron phase from the first. Exciting the pairs of skew quads thus allows the user to tune both phases of dispersion without interference from betatron coupling terms.

The tuning of the dispersion knobs was accomplished by varying a single knob and measuring the resulting beam size on the emittance wire scanners downstream of BC2. In the case of the BC1 dispersion knobs, it was found that all 4 wires had identical responses to the skew quads: in an initially-perfect lattice, exciting a BC1 dispersion bump increases the beam size on all 4 wires by the same factor. In practice, it was decided to use wire 4 to optimize the first dispersion knob (skew quads 1 and 2), and to use wire 2 to optimize the second dispersion knob (skew quads 3 and 4).

In the case of the BC2 skew quads, it was found that the wire response was highly unequal, and that the phase advance from the skew quads to the wires was not optimal. In this case a more complicated set of knobs was used, as shown in Table 2. In this configuration, knob 1 had the maximum effect on wire 1, while knob 2 had the maximum effect on wire 3.

Table 2: Configuration of BC2 dispersion knobs.

Knob	SQ1 coeff	SQ2 coeff	SQ3 coeff	SQ4 coeff
1	cos(15°)	-cos(15°)	sin(15°)	-sin(15°)
2	-sin(15°)	sin(15°)	cos(15°)	-cos(15°)

The tuning was performed by scanning the strength of each knob and, on each step of the scan, extracting the RMS vertical beam size at the desired wire. A parabolic fit was performed to the curve of beam size squared versus knob strength, and the knob would then be set to the value which, according to the parabolic fit, would minimize the measured beam size. The procedure included some additional logic to manage cases in which the scan range of the knob did not include the fitted minimum (ie, a rescan with a different range would be performed). The measured beam size was assumed to have no error or uncertainty, and the dynamic range of the wire scanner was assumed to be infinite (ie, the beam could not get so big that the wire scanner would fail). Tuning of the dispersion knobs is not iterated.

3 Results with BC1 Knobs Only

In the study [1], only the dispersion knobs in the first bunch compressor wiggler were used. We began by emulating this study. Table 3 shows the mean and 90% CL growths in the projected vertical emittance over 100 seeds.

Table 3: Emittance growths in simulations which emulate those described in [1].

Quad Offset (μm)	BPM Offset (μm)	Cavity Pitch (μrad)	Correction	Mean growth (nm)	90% CL Growth (nm)
150	7	0	KM	3.6	7.1
150	7	0	KM + Knobs	1.5	3.3
150	7	300	KM + Knobs	4.9	9.5

Comparison of Tables 1 and 3 shows that the recent simulations do not reproduce the original results. In particular, emittance growth is smaller in all cases in the more recent studies.

4 Results with BC1 and BC2 Knobs

Table 4 shows the results when both BC1 and BC2 dispersion knobs are used.

Table 4: Emittance growths in simulations which use both BC1 and BC2 dispersion knobs.

Quad Offset (μm)	BPM Offset (μm)	Cavity Pitch (μrad)	Correction	Mean growth (nm)	90% CL Growth (nm)
150	7	0	KM + Knobs	1.2	2.4
150	7	300	KM + Knobs	3.9	7.5

5 Summary and Future Directions

Table 5 summarizes the old and new simulation results.

Table 5: Summary of results from [1] and this study. All studies use KM steering as a first step.

Quad Offset (μm)	BPM Offset (μm)	Cavity Pitch (μrad)	Knobs	Mean growth (nm)		90% CL Growth (nm)	
				Old	New	Old	New
150	7	0	None	6.8	3.6	15.1	7.1
150	7	0	BC1	2.1	1.5	4.7	3.3
150	7	0	All	–	1.2	–	2.4
150	7	300	BC1	9.2	4.9	17.6	9.5
150	7	300	All	–	3.9	–	7.5

The studies performed here used the RMS beam sizes at the wire scanners as the independent variable in the tuning procedure. A more effective technique might be to fit a Gaussian to the beam spot and use the Gaussian width as the independent variable. This would suppress any over-weighting of non-Gaussian tails in the current study.

It is important to note that, although the dispersion knobs are effective in correcting the effects of the cavity pitch, the resulting emittance growth remains excessive: the mean growth after applying all corrections is almost as large as the emittance budget for the entire RTML, and the 90% CL is almost twice the budget. A more complete examination of the emittance budgets and mitigation techniques is required to ensure that the overall ILC emittance budgets can be met. Furthermore, the 2007 ILC configuration calls for a 9 mm RMS bunch length from the DR, which is larger than the 6 mm bunch used in this study. Although the bunch compressor configuration is being modified to reduce the voltage in BC1, which will to some extent reduce the emittance growth, we can expect that the emittance growth in the 2007 configuration will be worse than this. The growth in the "LowN" parameters, when the final bunch length must be reduced to 200 μm, will be even larger.

References

[1] K. Kubo, "Bunch Compressor KM steering – dispersion bump simulation – Vertical emittance dilution," presented at the 2007 EuroTeV / LET Meeting, Daresbury, UK (2007). Available

from `ilcagenda.cern.ch`.

[2] P. Tenenbaum, "Application of Kick Minimization to the RTML 'Front End'," SLAC-TN-07-002 (2007).